Physical and mechanical properties of anaerobic sealants

I. J. Toirov, *Z. L.* Batirov*, and *T.* Razzakov

Karshi Engineering-Economics Institute, Karshi, Uzbekistan

Abstract. The article presents the main causes of wear on the seats of rolling bearings during operation, which are fretting corrosion and turning of the inner and outer rings of bearings. Installed that an effective way to protect metal surfaces from fretting corrosion is to place an intermediate medium between them. Coatings with a small modulus of elasticity are applied to one or both contacting surfaces to create an intermediate medium. Using anaerobic sealants as coatings with a small modulus of elasticity is recommended. Anaerobic sealants, which are multicomponent liquid compositions capable of remaining in the initial state for a long time without changing properties, quickly cure at temperatures of 20-25° C and in case of violation of contact with oxygen in the air with the formation of a durable solid polymer. The application technology of anaerobic sealants is presented, and the influence of temperature, talc, and copper on the physical and mechanical properties affecting the durability of fixed joints is studied. According to the results obtained, using the AN-6K and AN-103 brands of anaerobic sealants is recommended as the most effective for restoring fixed joints of rolling bearings and increasing their durability. The article substantiates the influence of temperature and various fillers on the physical and mechanical properties of anaerobic sealants; based on these results, the brands of sealants suitable for restoring fixed joints from rolling bearings are recommended.

1 Introduction

To increase the durability of fixed joints, it is necessary to develop effective ways to protect the stretchable surfaces from fretting corrosion, which is the main cause of wear on the seats of rolling bearings.

The design and technological methods aim to prevent the relative displacement of the contacting surfaces or reduce it to a value that does not lead to a significant development of fretting corrosion by reducing the tangential force from an external load or increasing the friction force. It is possible to increase the friction force by increasing the coefficient of friction or the specific load between the contacting surfaces due to a decrease in the contact area, increased tension, or the use of special clamps. It is possible to increase the coefficient of friction by applying electroplating coatings. The application of copper tin leads to a decrease in damage during fretting corrosion.

*Corresponding author: botirov1972@inbox.ru

An effective way to protect metal surfaces from fretting corrosion is also to place an intermediate medium between them. Coatings with a small modulus of elasticity are applied to one or both contacting surfaces to create an intermediate medium. Electroplating coatings, cellulose, rubber, rubber, anaerobic sealants, and other polymeric materials are used as coatings with a small modulus of elasticity.

The contacting surfaces are protected from the effects of a corrosive environment by applying plastic and electroplating coatings, lacquer, and adhesive films. A layer of tin with a thickness of 1...2 microns increases the wear resistance of steel 45 in fretting corrosion conditions by 4...5 times.

The easiest way to implement these recommendations to increase the durability of fixed joints of rolling bearings during the repair of machines is by restoring them with anaerobic sealants. At the same time, there is no contact with metal surfaces; it is difficult to penetrate into the fixed joint of a corrosive and oxidizing medium; there is no setting, landing gaps are eliminated, dynamic loads are reduced, and turning of bearing rings is prevented.

Anaerobic sealants, which are multicomponent liquid compositions capable of remaining in the initial state for a long time without changing properties, quickly curing at temperatures of 20 ... 25 ° C and in case of violation of contact with air oxygen with the formation of a durable solid polymer [3].

The technological process of fixing the rolling bearing with an anaerobic sealant consists in cleaning the seating surfaces from corrosion; degreasing them with a swab soaked in acetone; applying the sealant to the mating surfaces, and leveling it with a brush; assembling and centering the connected parts curing the sealant before setting; removing the centering device; final curing of the sealant.

The conducted studies have shown that the durability of fixed joints of rolling bearings restored by anaerobic sealants depends on the physical and mechanical properties of sealants. However, the necessary data characterizing these sealants' physical and mechanical properties are very few in the literature. Therefore, we have conducted experimental studies to determine the destructive stresses, elongations, and specific work during the rupture of anaerobic sealants.

2 Materials and methods

The deformation and strength properties of the films were determined by the method and on the instruments of the Institute of Physical Chemistry of the Russian Academy of Sciences [1,2]. In this case, a thickness of 0.29-0.30 mm, a width of 5 mm, and a length of 40 mm were used, which were cast between two fluoroplastic plates. One of the plates had grooves 5 mm wide and 0.3 mm deep. To reduce the curing time, anaerobic sealants were added 0.1% of the accelerator – cobalt naphthenate (NK-1). Copper powder (GOST 4960-2017) and talc (GOST 19728.3-2001) were used as fillers. The effects of the type and concentration of performers on the deformation and strength properties of anaerobic sealants were evaluated using experiment planning according to the composite plan B_2. The concentrations of active X_1 (copper) and inert X_2 (talc) fillers were taken as independent factors, and the specific work at rupture Y was taken as an output parameter since the durability of the restored fixed joints depends on its value.

The deformation and strength properties of polymer films were determined on a horizontal small-sized breaking machine, the kinematic scheme of which is shown in Fig.1.

The test sample 2 (Fig.1) was fixed in clamps 1 and 3, one of which 3 moves freely along guide 4. The clamp 3 with screw 5 is driven in translational motion by a nut 6, the various rotation speeds of which are set by a reducer 7. When the sample 2 is stretched, the dynamometer plate 10 bends. An inductive sensor fixes the deflection value and is automatically recorded by a potentiometer 8 of the BV-662 type.

The loading speed of the sample was 10 mm/min; that is, it corresponded to the recommended GOST 11262-80, and the movement of the diagram tape was 120 mm/min. The accepted deformation rate ensured a uniform distribution of stresses over the sample. The discontinuous diagram was recorded on a potentiometer tape. The maximum sensitivity of the force measuring device is 0.1 n.

The destructive stress was determined by the formula [10].

$$\sigma_p = \frac{P}{F_o} \quad (1)$$

where P is the force at the moment of rupture; F_o is the cross-sectional area of the sample in the initial state.

The relative deformation of the ep was determined by the formula [10].

$$\varepsilon_p = \frac{\Delta l}{l} \cdot 100\% \quad (2)$$

The specific work of the gap was determined by the formula [11].

$$a_p = \frac{A_p}{F_0 l_0} = \int_0^{\varepsilon_p} \sigma(\varepsilon) d\varepsilon \quad (3)$$

where a_p is the specific work of the sample at break; A_p is the work of stretching the sample to break, determined by the area of the stretching diagram; $F_0 l_0$ is the corresponding initial cross-sectional area and length of the sample; σ, ε are respectively stress and elongation; ε_p is elongation at break; $\Delta\ell$ is absolute elongation, mm; ℓ is length of the working part sample, mm.

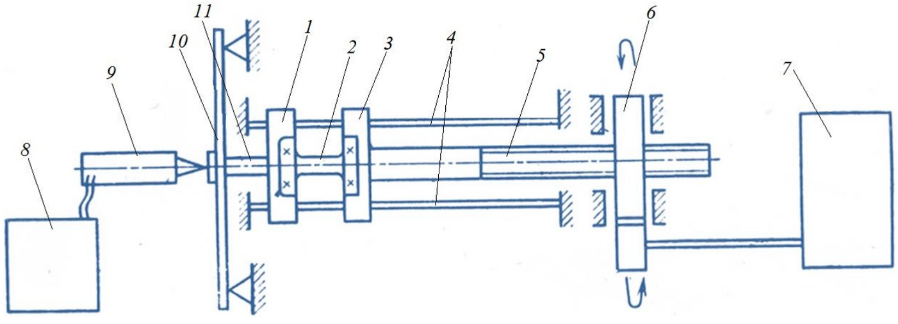

Fig. 1. Kinematic diagram of machine: 1,3 are clamps; 2 is sample; 4 is guides; 5 is screw; 6 is nut; 7 is reducer; 8 is potentiometer; 9 is sensor; 10 is dynamometer; 11 is– rod

3 Result and Discussion

The study results of the deformation and strength properties of anaerobic sealants show that they depend on the curing temperature.

Figure 4.1 shows the destructive stresses of anaerobic sealants UG-7, UG-8, AN-6, AN-6B, AN-6K, AN-103, and AN-104, cured at a temperature of 20°C. The strength of anaerobic sealants UG-7, UG-8, AN-6, AN-6B, AN-6K, AN-103, and AN-104 cured at a temperature of 20 ° C varies in a wide range of values. Thus, the destructive stresses of the

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sealants UG-7 and UG-8 are 33.1 and 34.7 MPa, and those of AN-6 and AN-6B are 21.9 and 22.7 MPa, respectively. The AN-6K sealant has the greatest destructive stresses (36.2 MPa), and the AN–104 sealant has the smallest (10.3 MPa). The destructive stresses of the AN-6K sealant exceed the destructive stresses of AN-104 by 3.5 times, AN-103 by 2.4 times, and AN-6 by 1.2 times.

The study results of the relative elongations of anaerobic sealants show that the sealants UG-7, UG-8, AN-6, AN-6B, and AN-6K have relatively low relative elongation readings.

The AN-6K sealant, which is the best in this indicator, has a relative elongation of 1.8 times higher compared to the UG-7 sealant, 1.6 times higher compared to the UG-8 sealant, and 1.5 times higher than the AN-6.

The AN-103 and AN-104 sealants have higher elongations compared to those listed. The relative elongations of the AN-103 sealant are 18.5 times, and the AN-104 sealant is 24.2 times higher than the relative elongations of the UG-7 sealant.

Specific works at the rupture of anaerobic sealants show that the UG-7 sealant has the minimum specific work (0.98 MJ/m^3), and the AN-103 sealant has the maximum (12.3 MJ/m^3). Specific work at the rupture of anaerobic sealants UG-8, AN-6, AN-6B, and AN-6K occupy an intermediate position. Of these, the AN-6K sealant has the largest specific work at rupture (2.9 MJ/m^3), which is almost 3 times higher than the specific work at rupture of the UG-7 sealant, 2.4 times – UG-8 and 1.5 times – AN-6.

Studies have shown that anaerobic sealants' deformation and strength properties also depend on the curing temperature. The effect of the curing temperature on the destructive stresses σ_p, relative elongations ep, and the specific work at rupture of the anaerobic sealant AN-103 is shown in Fig.1.

In curing temperatures of 20-120° with an intense increase in destructive stresses is observed. For example, the destructive stresses of the AN-103 sealant, cured at 80°C, are 1.3 times greater, and cured at 120°C are 1.7 times greater than those cured at 20°C.

The AN-103 sealant has the maximum elongation at a curing temperature of 20 ° C. With an increase in the curing temperature, the elongation decreases. For example, the relative elongations of samples cured at 60°C decrease from 98 to 57%, that is, by 1.7 times, and samples cured at 120°C – at 98 to 36%, that is, by 2.7 times compared with the relative elongations of samples cured at 20°C.

With an increase in the curing temperature of anaerobic sealants, the specific work at rupture decreases. The maximum specific work at rupture is observed in samples cured at 20°C. For example, the specific work at the break in samples cured at 60°C decreases by 1.2 times, and at 120°C – by 1.5 times.

The specific work of deformation at break is a measure of the working capacity of the material. Therefore, the durability of fixed joints restored by anaerobic sealants should decrease with increased curing temperature under dynamic loading.

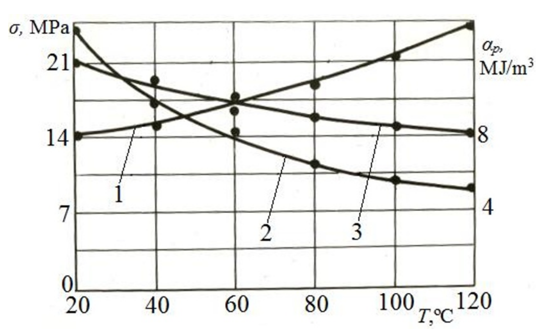

Fig. 1. Dependences of destructive voltage σ_p, relative elongation ε_p, and specific work of a_p on curing temperature of anaerobic sealant AN-103.1, 2, 3 are respectively ε_p, a_p and σ_p

The specific work of deformation at break is a measure of the working capacity of the material. Therefore, the durability of fixed joints restored by anaerobic sealants should decrease with increased curing temperature under dynamic loading.

The specific work at rupture is also reduced when inert fillers are introduced into the composition of anaerobic sealants. The specific work during the rupture of samples from anaerobic sealant AN-104 filled with copper and talc powders was determined using the theory of experiment planning according to composite plan B_2.

As a result of experimental data, a mathematical model was obtained that adequately describes the dependence of the specific work at the break on the concentration and type of fillers (Appendix 11).

The regression equation has the form

$$У=5.155+0.236\,X_1+0.071\,X_2 - 0.028\,X_1X_2 - 0.0028\,X_2^2$$

where X_1 is the concentration of copper, 0.01-0.04 mass fractions; X_2 is talc concentration, 0.005-0.025 mass fractions.

The analysis of the equation showed that when active (copper) and inert (talc) fillers are introduced into the anaerobic sealant AN-104, the specific work at rupture decreases. Thus, with a content of 0.01 mass fraction of copper and 0.05 mass fraction of talc, the specific work at rupture is 5.5 MJ/m^3(Fig.3). The specific work when the anaerobic sealant AN-104 breaks without fillers is 7.4 MJ/m^3. However, the work of the sealant with filler is 26% lower than the specific work of the sealant with a talc content of 0.05 mass fraction without filler. With an increase in the copper content to 0.04 mass fraction, the specific work at break increases slightly and reaches 5.9 MJ/m^3, which is 80% of the specific work at break

Dependences of the specific work at the rupture of the ap on the concentration of copper

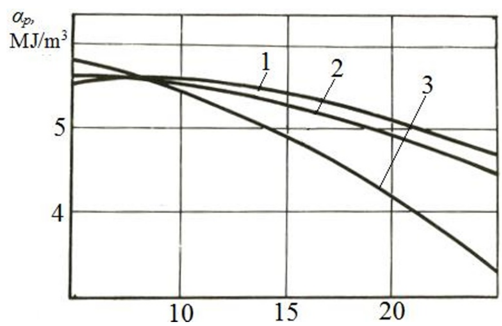

Fig. 2. Talc concentration: 1 – 0.05; 2 – 0.15; 3 – 0.025 mass shares

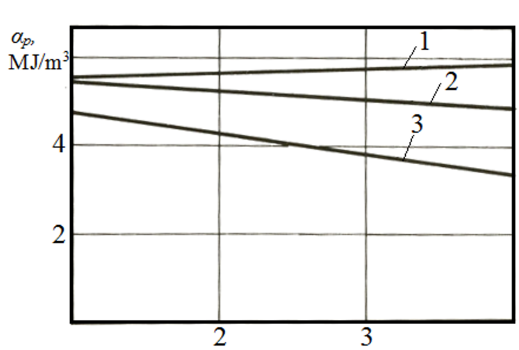

Fig. 3. Dependences of specific work at rupture of a_p on concentration of talc
Cope concentration: 1 – 0.01; 2 – 0.025; 3 – 0.04 mass shares

An increase in the specific work at the break with an increase in the active filler (copper) content is associated with an increase in the strength of the composition.

The specific work at break is significantly reduced with an increase in the concentration of inert filler (talc). Thus, with a talc content of 0.25 and copper 0.01 mass fractions, the specific work at rupture is reduced by 45% compared to the specific work of a sealant without fillers. A decrease in the specific work at the break with an increase in fine inert filler (talc) concentration is associated with a drop in destructive stresses and elongations at the break.

Thus, studies of the deformation and strength properties of anaerobic sealants have shown that in anaerobic sealants, depending on the curing mode, destructive stresses, elongations, and specific work at break vary widely. This is because during the curing process at high temperatures, the depth of polymerization increases, as a result of which the density of the physical and chemical meshes increases, contributing to an increase in the rigidity of the polymer. Bench tests of rolling bearings under circulating loading of the outer ring have shown that the durability of rolling bearings depends on the brand's nature and the sealant layer's thickness. When installing a rolling bearing in a housing with a tension of 0.005 mm (without polymer), the durability is reduced by 9.4% compared to the calculated one. When restoring the fit of the outer ring of the bearing with anaerobic sealants, the durability of the bearing increases. For example, when restoring the fit of the outer ring of the bearing with an anaerobic sealant UG-7 with a thickness of 0.081 mm, the durability of the bearing is 2.8 times higher compared to the calculated one. The durability of rolling bearings increases with an increase in the thickness of the adhesive layer and its elasticity. Thus, when the bearing is restored with AN AN-6K sealant with a thickness of 0.137 mm, the durability of the rolling bearing increases by 4.2 times compared to the calculated one.

However, the durability of the restored fixed joints decreases with increasing clearance. Therefore, it is recommended to restore fixed housing-bearing joints with a gap of up to 0.16 mm, AN-6K - up to 0.27 mm, and AN-103 - up to 30 mm with an anaerobic sealant UG-7.

4 Conclusions

1. Anaerobic sealants, depending on the brand, have different deformation and strength properties. The AN-6K sealant has the maximum destructive stresses at the break, the AN–104 has the maximum elongation, and the AN–103 has the maximum specific work at the break. With increased curing temperature, the destructive stresses increase, and the elongation and specific work at break decrease.

2. The durability of fixed joints restored by anaerobic sealants depends on the gap before restoration. With an increase in the gap, the durability of fixed joints decreases. It is recommended to restore the landing of the outer rings of rolling bearings with anaerobic sealants at gaps: UG-7 up to 0.16 mm, AN-6K - up to 0.27 mm, and AN-103 - up to 0.3 mm.

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